Unitil
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FG&E High-Pressure Gas Planning Study 1999

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Contents

EXECUTIVE SUMMARY

The Fitchburg gas high-pressure system was studied by the System Planning group of Unitil's Engineering Department to determine what expansion plans should take place as part of the Strategic Gas Expansion Initiative for Unitil Corporation. The study focuses on three key deliverables: 1) Provide a current, updated high-pressure gas system planning model for future use, 2) Provide documentation in the form of a study report, and 3) Develop a long term, detailed Capital Expansion Plan.

The system serves over 15,000 customers in the Massachusetts towns of Fitchburg, Westminster, Gardner, Lunenburg, Ashby, and Townsend. It operates at a maximum pressure of 100 psig and serves end-use customers, intermediate pressure systems, and two low-pressure systems in Fitchburg and Gardner. Gas is currently supplied to the high-pressure system at two locations: Tennessee Gate Station & Liquefied Propane Plant (LPG), located on Pleasant St. in Fitchburg, and Liquefied Natural Gas (LNG) Plant, located on West State Rd. in Westminster.

To provide the study deliverables, two objectives were considered. The first was to ensure that firm customers have gas available even on abnormally cold days. The second was the need for an economic design of the system. Planning ensures that the system will meet realistic requirements. This helps Unitil design more efficient systems, minimizing capital investment. The study focused on two separate criteria (both are part of the Unitil Gas Planning Criteria). The first was to maintain the minimum pressure criteria within the system and the second requires backup supply for both the LNG and LPG plants under all design conditions.

Study results indicate FG&E's gas high-pressure system is capable of supplying peak hour, firm loads under current, peak design day conditions. There is additional capacity available within the system, enough to support up to 10% growth, requiring no system improvements. Improvement projects are required at 12%, 18%, 22%, 25%, and 30% growth. Various projects were studied for each of these growth rates. All projects were compared using present day costs and do not include escalation for inflation. The result of these studies are the following five projects:

Project #1-12%: $120,000 -- Upgrade 4 Low Pressure regulator stations in Gardner.

Project #2-18%: $ 78,100 -- Reinforce piping to Regan St. in Gardner and improve sendout piping from the Gate Station in Fitchburg.

Project #3-22%: $136,500 -- Improve sendout piping from the Gate Station in Fitchburg.

Project #4-25%: $370,500 -- Reinforce piping within Fitchburg to improve minimum pressures in Gardner.

Project #5-30%: $286,000 -- Reinforce piping between the LNG plant and Gardner (this project is outside of the study period for all growth scenarios).

Projected time-lines for the recommended projects depend upon anticipated growth rates, as identified in the Market Potential Study (MPS). The MPS was completed as part of the Strategic Gas Expansion Initiative and identified four growth scenarios for the gas system. Three of these apply to this study. The following table identifies when each project should be completed, for each of these scenarios, to maintain adequate system capacity and pressures, based on the design criteria. The table assumes the base year is 1998 and the first year of growth is 1999 (calendar years).

Year / Growth Scenario	Base Line: 1% Annually	Expected: 2% Annually	Expected Budget	Aggressive: 3.5%/Yr. – 4 Yrs., 2%/Yr. – 6 Yrs.	Aggressive Budget
1999					
2000					
2001					
2002				1-12%	$120,000
2003					
2004		1-12%	$120,000	2-18%	$ 78,100
2005					
2006					
2007				3-22%	$136,500
2008		2-18%	$78,100	4-25%	$370,500
Total Cost			$198,100		$705,100

A schematic of the FG&E Gas System with the recommended projects is in appendix A or can be seen at the following link: Gasdwg.doc

With the completion of all five improvement projects, the FG&E gas system would have the ability to provide up to 36% additional gas to its growing customer base. This would translates to over 400Mcfh which, as an example, could provide gas to over 2600 residential customers (150cfh per customer).

Based on the findings in this study, it is the recommendation of the Engineering Department that FG&E Light Company design and construct the identified projects based on the load growth scenario chosen in the Strategic Gas Expansion Initiative.

INTRODUCTION

Gas systems are designed to serve customers safely and efficiently, with minimal service interruptions. The methodology used to do this assumes the customer can perform their normal daily routines without any knowledge of how the gas is being delivered to their premise. Gas planning is a part of Unitil's effort to meet that service commitment. Planning ensures the performance of the gas system by anticipating service needs and by identifying designs to satisfy future changes. It promotes safety and efficiency by identifying alternatives that allow the careful selection of pipeline routes and equipment locations.

The specific objective of gas planning is to ensure that firm customers have gas available even on abnormally cold days. This objective is balanced by a second, which is the need for economy of design. Planning ensures that the system will meet realistic requirements, which helps Unitil design more efficient systems that minimize capital investment. Uneconomic design results in operational inefficiencies and increased construction costs, which ultimately translate into higher rates, making Unitil a less competitive energy supplier.

The purpose of this particular study is to evaluate the Fitchburg gas high-pressure system to determine what expansion plans should take place as part of the Strategic Gas Expansion Initiative for Unitil Corporation. The study focuses on three key deliverables: 1) Provide a current, updated high-pressure gas system planning model for future use, 2) Provide documentation in the form of a study report, and 3) Develop a long term, detailed Capital Expansion Plan.

This study will concentrate on the available capacity of the Fitchburg high-pressure gas system during a system peak. The peak will be analyzed at a single point in time using hourly load and supply information. This assumes the FG&E gas system operates statically, with little or no transient effects. All loads will be described in units of Mcfh or thousands of cubic feet of gas per hour. For the purposes of this study, Mcfh are essentially equal to decatherms per hour . The results of this study, although producing exact numbers, can only be used as a tool to predict the actual system's performance. The actual performance may be better or worse than predicted and should be validated as the actual system conditions develop.

SYSTEM DESCRIPTION

The Fitchburg gas high-pressure system serves the Massachusetts towns of Fitchburg, Westminster, Gardner, Lunenburg, Ashby, and Townsend. The high-pressure system operates predominately with a Maximum Allowable Operating Pressure (MAOP) of 100 PSIG and serves two low pressure systems (with MAOP's of 14 inches water column), one in Fitchburg and the other in Gardner. Gas is currently supplied to the system at two locations: Tennessee Gate Station & Propane Plant, located on Pleasant St. in Fitchburg, and Liquefied Natural Gas (LNG) Plant, located on West State Rd. in Westminster (see system map in Appendix A).

The Gate Station serves as primary supply into the gas system. FG&E has contracted with Tennessee Pipeline Company for firm gas service to the gate station from a transmission line owned by Tennessee. The line is a transmission lateral, radially feeding from the south and ending in Fitchburg at the gate station. Currently, maximum daily supply (referred to as MDQ or maximum daily quantity) is contractually limited to 14,041 Mcfh. No more than 6% of this MDQ can be taken in any given hour, which means FG&E's maximum hourly supply is contractually limited to 842 Mcfh.

Additional supply is available from FG&E's Propane and LNG plants. Approximately 10 years ago, FG&E received approval from the Energy Facility Siting Council (EFSC) to operate the propane plant up to a maximum hourly capacity of 300 Mcfh. This translates to a daily capacity of 7200 MCF per day. The LNG plant is limited to 250 Mcfh due to operating requirements related to Unitil planning criteria. The planning criteria stipulates FG&E maintain backup supply for the first contingency loss of the LNG plant. A portable vaporizer (FG&E purchasing unit in 1999) with a backup supply capability of 250 Mcfh is what limits the allowable output of the LNG plant. The LNG plant is capable of supplying up to 300 Mcfh without this limitation.

The high-pressure piping system is made up of a network of steel and plastic pipe. Gas is transported through this network to low pressure regulators and customer service points. A single pipe (6-inch & 8-inch) through Westminster connects Gardner and Fitchburg. The LNG plant provides support to the Gardner area when system pressures decrease due to pressure loss from the gate station supply point in Fitchburg. Without this support, the system would not maintain adequate pressures in the Gardner area on days when the temperature reaches approximately 10 degrees Fahrenheit or less. Additionally, the LNG plant can provide some gas supply back toward Fitchburg if required. In this situation, regulators located at Sawyer Passway and Chubbs Pier are utilized to lower the pressure from the gate station towards Gardner, allowing the LNG plant to supply more gas into the Fitchburg area. Ashby and Townsend are fed from Fitchburg by two 4-inch pipes. One pipe runs along Route 31 to Ashby and the other along Route 13 to Townsend. The two pipes are looped between Ashby and Townsend along Route 119. A system map is included in Appendix A as a reference.

ANALYSIS

Analyzing a high-pressure gas system requires a detailed assessment of the physical system, customer classes, usage profiles, operating procedures, and fluid characteristics. The result is a capacity model of the system, which include new operating requirements and recommended changes for the system.

An analysis of this kind has a number of steps. First, a thorough review of system maps, operating procedures, construction techniques, and past planning studies are completed. Next, loads are developed for the system based on actual customer usage information. A system model present day case is then developed. The present day case must be validated with actual field data before moving on to the next step. Next, a design day, base case is developed to model existing worst case conditions. The base case will be the model that all other cases are developed from. With a base case completed, future cases are developed to allow for growth and define alternatives. Finally, alternatives are reviewed in an economic analysis and recommendations are made. Each of these steps are discussed below.

A. Load Development

A comprehensive and rigorous analysis was performed to establish the peak hour, base case loading. Empirical system pressure data was used to calibrate the model's performance and validate system loading. Weekly pressure charts and System Dispatcher gas system logs were the source of the pressure data. Load data was established by collecting and reviewing data from previous system models, System Dispatcher's daily gas log sheets, individual electronic customer meters and a listing, by meter route, of historical billing data for all active gas accounts within the system. The load data is converted to a format that can be used in modeling the system. During this conversion, two customer groups are separated from one another, firm and interruptible. Design criteria requires continuous service to our firm customers only (the exceptions are maintenance, operating, or contingency situations). Within the FG&E gas system, there are approximately 10 customer accounts supplied under interruptible contracts. The remaining customers are all considered firm. Throughout the report, the inclusion or exclusion of these specific individual interruptible loads will be noted as required.

Load growth will be included in future case modeling. Growth projections were developed in the Market Potential Study portion of the Strategic Gas Expansion Initiative. Various growth scenarios were identified and studied. Detailed descriptions of this and other parts of the load development process are included in Appendix B.

B. Base Case Modeling

The present day case simulates the peak hourly flow condition at 7:00 a.m. on January 21, 1998. Firm customers were included based on meter route usage for the month of January and daily electronic meter data. Interruptible customers were included based on the actual data captured from the System Dispatcher's gas log sheet for the specific date simulated. These sheets depict which interruptible customers were operating throughout the day. Additional pressure information was used from the gas system logs.

System logs show pressure settings of 99 psig at the Gate Station and 91 psig at the LNG plant at 7:00 a.m. on January 21, 1998. The Propane plant was not operating. System sendout at the time was approximately 690 Mcfh at the Gate Station and 210 Mcfh at the LNG plant. Combining this information with the present day loads developed earlier, a present day case model was developed and tested. The results of this simulation were very accurate except for the pressure settings at the LNG plant (which were changed in the model from 91 to 94 psig as a result of the validation process). With known pressures set at the Gate Station and LNG plant, and known base loads, the model simulated system pressures and sendout. Comparing simulated system sendout to actual field data showed less than a 1% difference. Additionally, pressures throughout the system were accurate to within 2% of actual field data. This case validates the accuracy of both the physical piping system and load distribution within the model. With this initial model completed, design day, base case models will be developed.

Actual Field Data				**Model Results**				**Actual/Model**
P_{LNG}	Q_{LNG}	$P_{TGP/LPG}$	$Q_{TGP/LPG}$	P_{LNG}	Q_{LNG}	$P_{TGP/LPG}$	$Q_{TGP/LPG}$	**Accuracy**
91	**209**	**99**	**697**	**94**	**207**	**99**	**691**	**>98%**

Before creating these cases, design conditions must be defined. For this study, two design day conditions will be utilized. The first design day condition, Abnormal Peak Day (APD), is defined as the coldest day expected to recur once every 30 years. APD design conditions are modeled with all firm and no interruptible loads. This day is considered to be a first contingency emergency under Unitil's gas planning criteria. The second design day condition, Cold Winter Day (CWD) is defined as the coldest day expected to recur once every year. CWD design conditions are modeled with all firm and interruptible loads. The current associated heating degree day[1] (HDD) values are APD= 70 HDD[2] and CWD= 63 HDD. Both of these have been filed with the Massachusetts Department of Telecommunications and Energy[3].

Developing the design day base cases for both APD and CWD requires a method to project load information for firm customers from a validated existing case to the design day conditions. For this study, the projection was developed by comparing historical daily sendout information versus the corresponding HDD[4]. The resulting scatter plot yielded a straightline equation, which was utilized to determine daily sendout information for the APD and CWD design conditions. Daily sendout was then used to determine a corresponding peak hour sendout factor[5]. Comparing historical peak hour sendout figures versus the corresponding daily firm sendout provided the information needed to develop this factor. Additionally, specific peak hour factors were reviewed from actual field data to verify the accuracy of the calculated factor. The review showed that the calculated peak hour factors were slightly lower than actuals due to higher daily sendout figures utilized in the calculation. It was determined the actual values would be utilized in determining the

[1] AGA – GEOP: Volume III, Book D-1, Part 1, Weather-Load Relationships, Degree Days

[2] Maximum HDD change. Previously, FG&E assumed a 73 HDD peak design day. New studies by the Finance department indicate the peak HDD should be 70. This lower design value has been adopted as the system design standard.

[3] DPU decision 94-140

[4] AGA – GEOP: Volume III, Book D-1, Part 1, Weather-Load Relationships, Degree Days

[5] AGA – GEOP: Volume III, Book D-1, Part 1, Weather-Load Relationships, Load Curve & Load Factors

peak hour load. This is a slightly more conservative approach (less than 5% difference) but will ensure the integrity of the system. The resulting projected loads for each design day condition are Q_{APD}= 1135Mcfh and Q_{CWD}= 1066Mcfh. See Appendix B for detail on the methods used and results found in developing these load projections.

Design Day	HDD	Q
APD	70	1,135 Mcfh
CWD	63	1,032 Mcfh

Design day base cases for both APD and CWD conditions were created with the loads developed above. This was done by uniformly growing the firm loads, developed in the present day case model, to APD and CWD loads levels. The resulting models represent the FG&E gas high-pressure system under present day, design level conditions.

The APD model shows that the existing system has adequate capacity to serve it's existing firm customers. This assumes that all 3 supply sources (TGP, LNG, & LPG) are operating at the following levels:

Supply	Sendout P	Sendout Q
TGP& LPG	100psig	883Mcfh
LNG	88psig	250Mcfh

Minimum pressure locations within the system are at Regan St. in Gardner(P_{GEOL}) and Timberly Park in Townsend(P_{TEOL}). Pressure levels for these two locations are P_{GEOL}= 60psig and P_{TEOL}= 45psig.

Although the CWD firm loads shown in the table above are lower than an APD, analyzing the CWD model was more complicated because of the introduction of interruptible customers. Even though the system pressures are adequate, the model shows too much of a supply requirement from the LNG plant. Increased supply from the LNG plant (above 250Mcfh operating limit) can be considered. Another alternative is to operate the new portable vaporizer in this CWD condition as a peak shaving unit. This would be an acceptable alternative relative to Unitil's design criteria as the interruptible customers could be shut off in the event of an emergency.[6] This alternative needs further review to determine if it is economically feasible. The following table shows the anticipated supply requirements of the 3 supply sources and the recommended sendout pressures:

Supply	**Sendout P**	**Sendout Q**
TGP&LPG	**100psig**	**1080Mcfh**
LNG	**78psig**	**295Mcfh**

Minimum pressures within the system are P_{GEOL}= 40psig and P_{TEOL}= 45psig. If the LNG plant is limited to 250Mcfh sendout, minimum pressure levels are not adequate. Because of their interruptible status, we do not consider them in our decisions to upgrade the system. Therefore, only the APD case will be studied in future cases.

[6] Cost of procurring LNG and operating the LNG plant or portable vaporizer have not been considered in this study analysis.

C. Future Case Modeling

Future cases are developed to model projected growth patterns and major system changes. For this study, growth projections developed in the Market Potential Study portion of the Strategic Gas Expansion Initiative were used to develop future cases. Five possible growth scenarios were identified. Three scenarios apply to this analysis: Base Line, Industry Average, and Aggressive. Each scenario was based on an annual percentage growth rate within the Gardner, Westminster, and Fitchburg areas. No growth was projected in Ashby and Townsend. The differences between the scenarios was the time required to add the anticipated growth. Over a 10 year period, the scenarios range from a total increase from 6% to 25%. For the purposes of this study, the following growth rates were analyzed in separate cases:

Growth Rate Cases														
1%	2%	4%	6%	10%	12%	14%	16%	18%	20%	22%	24%	25%	30%	36%

Details and printouts of each case are located in appendix D.

As each case was modeled, design criteria (Loss of one plant, either LNG or LPG) were compared against the results to determine if the system could serve the added load growth. The system was able to adequately meet all design criteria for cases up to and including 10% growth.

At 12% added load and Q_{System}= 1259Mcfh, the system went below minimum design levels in Gardner with P_{GEOL}= 35psig. Two alternatives were compared and "fgeAPDDesignDay12%FIX2" was selected as the best solution. Essentially, this alternative ugrades all 4 regulator stations within Gardner to allow the minimum pressure criteria in Gardner to be lowered to 20psig. Existing criteria is $P_{min} \geq$ 40psig because current regulator equipment requires high, pressure differentials. With this change, the system is capable of meeting design levels for load increases up to and including 16%.

Case Name	**Growth Rate**	**Q_{System}**	**P_{GEOL}**
fgeAPDDesignDay12% - without solutions	**12%**	**1259**	**35**
fgeAPDDesignDay12%FIX2	**12%**	**1259**	**35**

At 18% growth and Q_{System}= 1321Mcfh, minimum pressures are P_{GEOL}= 13psig, which are below design requirements. Five alternatives were studied with solution #18-2, "fgeAPDDesignDay18%FIX2" being the best solution. This alternative recommends installing approximately 600 feet of 4" plastic pipe to increase system pressure to Regan St. regulator station. In addition, approximately 1200 feet of 8" plastic pipe is required in parallel with existing pipe on Pleasant St., from the TGP Gate Station to Lunenburg Avenue. Minimum pressures are P_{GEOL}= 30psig after making these changes and stay within design requirements up to and including a 20% load increase.

Case Name	**Growth Rate**	**Q_{System}**	**P_{GEOL}**
fgeAPDDesignDay18% - without solutions	**18%**	**1321**	**13**
fgeAPDDesignDay18%FIX2	**18%**	**1321**	**30**

At 22% growth and Q_{System}= 1363Mcfh, minimum pressure drops below design requirements, with P_{GEOL}= 15psig. Six alternatives were studied to solve this problem. Solution #22-4, "fgeAPDDesignDay22%FIX4" was chosen as the best alternative. It requires the installation of 2100 feet of 8" plastic pipe in parallel with existing pipe located in FG&E right-of-way, from the TGP Gate Station to Chubbs Pier Station. Minimum pressures are P_{GEOL}= 25psig after making these changes and stay within design requirements up to and including a 24% load increase.

Case Name	Growth Rate	Q_{System}	P_{GEOL}
FgeAPDDesignDay22% - without solutions	22%	1363	15
FgeAPDDesignDay22%FIX4	22%	1363	25

At 25% growth and Q_{System}= 1394Mcfh, minimum pressure drops below design requirements, with P_{GEOL}= 12psig. Additionally, maximum system supply quantities were reached at this load level. Beyond 25% growth will require additional firm supply. Ten alternatives were studied for this problem. Solution #25-6, "fgeAPDDesignDay25%FIX6" was chosen as the best alternative. This solution calls for the installation of 5,700 feet of 8" plastic pipe from Chubbs Pier to Sawyer Passway. Minimum pressures are P_{GEOL}= 35psig after making these changes and stay within design requirements up to an including a 28% load increase.

Case Name	Growth Rate	Q_{System}	P_{GEOL}
FgeAPDDesignDay25% - without solutions	25%	1394	12
FgeAPDDesignDay25%FIX6	25%	1394	35

Additional growth scenarios were studied which required a solution at 30%. This study assumes that additional supply quantities, exceeding the existing system limit of 1392Mcfh by 54Mcfh or more, are available during peak hour situations. Total system sendout for this case is Q_{System}= 1446Mcfh. Minimum pressures, P_{GEOL}= 21psig, are just above design levels but are too sensitive to pressure variations at the LNG plant. For example, reducing P_{LNG} from 80 to 75psig lowers P_{GEOL} to 4psig. Two alternatives were studied to solve this problem. Solution #30-1, "fgeAPDDesignDay30%FIX1" was chosen as the best alternative. It recommends the installation of approximately 4,400 feet of 8" plastic pipe along the existing pipe, from the LNG plant to the Gardner Town border. Minimum pressures are P_{GEOL}= 38psig after making these changes and stay within design requirements up to an including a 36% load increase.

Case Name	Growth Rate	Q_{System}	P_{GEOL}
FgeAPDDesignDay30% - without solutions	30%	1446	21
FgeAPDDesignDay30%FIX1	30%	1446	28

A summary listing of the recommended alternatives is shown in the Results of this section. A listing of all models studied is shown in Appendix C.

D. Alternative Analysis

Alternatives are solutions to problems found during either base or future case modeling. Typically, alternatives are only considered viable if they satisfy all design criteria. In this study, problems can occur in the following situations: System pressures drop below minimum pressure criteria, system pressures are too sensitive to source pressure fluctuations, and/or supply limits are exceeded. When these situations occur, an alternative analysis is needed to objectively compare alternatives from a financial basis. Supply limit violations will not have an alternative analysis performed but will be noted during this study. The Procurement department will deal with these issues. In making final recommendations, the analysis also considers safety and reliability. Results of the alternative analysis are comprehensive and efficient recommendations to remediate all problems found during the course of the overall study.

During this study, an alternative analysis was performed for 5 separate cases where design criteria were not met. Several assumptions were made during this analysis. First, it was assumed that all projects studied used the same cost basis (with the exception of the 2 studied for the 12% growth case, which were specifically estimated). The basis for this study is $65 per foot of 8" plastic pipe (fully loaded contract costs). Additionally, sensitivity to pressure variations at the LNG plant and system reliability were also considered prior to choosing a specific project. All projects were compared using present day costs and do not include escalation for inflation.

Recommended solutions, based on their alternative analysis, are shown in the following section. A more detailed listing of alternatives can be found in Appendix C.

E. Results

This analysis recommends 5 projects, which are completely dependent on the growth rates within Fitchburg, Westminster, and Gardner. A Critical path planning analysis was performed to determine the effects of constructing the recommended projects or other alternatives at different load levels and in different order. The 5 projects summarized below are recommended based on this analysis and should be constructed in the order presented.

Summary of Recommended Alternatives

Project #1-12%: 12% Growth → Upgrade 4 Low Pressure regulator stations in Gardner.

Description: Install new regulator equipment and piping at Regan St., Logan St., Pearson Blvd., and Kraft St. regulator stations. Re-design stations from inlet to outlet piping including but not limited to valves, regulators, pilots, bypass piping, elbows, inlet & outlet piping, tubing, and pressure relief valves.

Estimated Cost: $120,000

Justification: This project is required to allow FG&E to lower their minimum pressure planning criteria for the Gardner area to 20psig. Current criteria requires FG&E maintain a 40psig minimum.

Project #2-18%: 18% Growth → Reinforce piping to Regan St. in Gardner and improve sendout piping from the Gate Station in Fitchburg.

Description: Install 600 feet of 4" plastic pipe on Parker St. in Gardner, from Greenwood St. to Regan St. Additionally, install 1200 feet of 8" plastic pipe on Pleasant St. in Fitchburg, from the Gate Station to Lunenburg St.

Estimated Cost: $78,100

Justification: Regan St. regulator is the current, minimum pressure location in the Gardner high-pressure system. Models indicate under this growth scenario, that this location is below new minimum pressure criteria of 20psig and operates approximately 10psig lower than the rest of the Gardner system. Installing a 4" tie between Greenwood and Regan streets increases the Regan St. pressure to within 3psig of the rest of Gardner. Additionally, reducing pressure loss directly out of the Gate Station in Fitchburg by installing 8" pipe up Pleasant St., is required to bring Gardner pressure up above the minimum pressure criteria.
Min. P_{before}= 13.1psig / Min. P_{after}= 30.2psig

Project #3-22%: 22% Growth → Improve sendout piping from the Gate Station in Fitchburg.

Description: Install 2100 feet of 8" plastic pipe along existing right of way from the Gate Station to Chubbs Pier.

Estimated Cost: $136,500

Justification: This new piping is required to maintain system minimum pressures above design levels. This project was compared against 5 other projects and determined to be the least cost alternative. In addition, this project will improve overall system pressures by reducing the pressure losses incurred by the existing sendout piping from the Gate Station in Fitchburg which have the highest pressure loss values in the entire high-pressure system. One added benefit is that this project takes the first step towards the long term goal of improving the piping system between Fitchburg and Gardner.
Min. P_{before}= 15.4psig / Min. P_{after}= 25.1psig

Project #4-25%: 25% Growth → Reinforce piping within Fitchburg to improve minimum pressures in Gardner.

Description: Install 1400 feet of 8" plastic pipe on John Fitch Highway, from Chubbs Pier to Lunenburg St., 1700 feet of 8" plastic pipe on Lunenburg St., from John Fitch Highway to Winter St., and 2600 feet of 8" plastic pipe on Winter St., from

Boutelle St. to Sawyer Passway. A total of 5700 feet of 8" plastic is required for this project.

Estimated Cost: $370,500

Justification: This project is required to increase minimum pressure levels back above design requirements within Gardner. Ten projects were analyzed. This project is recommended because it is the least cost alternative to pass both the pressure and sensitivity analysis performed.
Min. P_{before}= 12.9psig / Min. P_{after}= 35.4psig

Project #5-30%: 30% Growth → Reinforce piping between the LNG plant and Gardner. Note that this project assumes additional supply has been obtained for the system and is available at the TGP/LPG site.

Description: Install 4400 feet of 8" plastic pipe on Shady Ln. and Partridge Rd., from the LNG plant to the Gardner/Westminster town line.

Estimated Cost: $286,000

Justification: This project is required to decrease system minimum pressure sensitivity to variations in sendout pressures at the LNG plant. Small decreases in sendout pressure at the LNG Plant of 1psig or more cause minimum pressures in Gardner to go below design requirements. Several projects were reviewed. Two of these projects were considered reasonable solutions. The least cost alternative was chosen as the best solution.
Min. P_{before}= 21.1psig / Min. P_{after}= 38.3psig

CONCLUSION

The FG&E gas high-pressure system is capable of supplying peak hour, firm loads under current design day conditions. There is additional capacity available within the system, up to 10% growth, requiring no system improvements. Improvement projects are required at 12%, 18%, 22%, 25%, and 30% growth (each rate is based on 1999 peak hour, load levels). These projects are listed in Table A below.

Projected time-lines for the recommended projects depend upon anticipated growth rates, as identified in the Market Potential Study. Tables B and C identify when each project should be completed for each of the 5 scenarios identified in the Market Potential Study. Note the years shown are based on 1999 as the base year, and 2000 as the first year of growth.

Table A: Recommended Projects

Project #	Cost	Model Name	Growth Rate	Description
1-12%	$120.0 K	fgeAPDDesignDay12%FIX2	12%	Upgrade 4 Low Pressure regulator stations in Gardner
2-18%	$ 78.1 K	fgeAPDDesignDay18%FIX2	18%	Reinforce piping to Regan St. in Gardner and improve sendout piping from the Gate Station in Fitchburg
3-22%	$136.5 K	fgeAPDDesignDay22%FIX4	22%	Improve sendout piping from the Gate Station in Fitchburg
4-25%	$370.5 K	fgeAPDDesignDay25%FIX6	25%	Reinforce piping within Fitchburg to improve minimum pressures in Gardner
5-30%	$286.0 K	fgeAPDDesignDay30%FIX1	30%	Reinforce piping between the LNG plant and Gardner
Total	**$991.1 K**	**Project costs are based on 1999 fully loaded contract costs (all piping is 8" Plastic)**		

Table B: Project Time-lines

Project #	Base Line: 1% Annually	Industry Average: 2% Annually	Aggressive: 6% Annually
1-12%	N/A	2004	2002
2-18%	N/A	2008	2004
3-22%	N/A	N/A	2007
4-25%	N/A	N/A	2008
5-30%	N/A	N/A	N/A

Table C: Budget Time-line by Project & Cost

Year	Base Line: 1% Annually	Industry Average: 2% Annually	Industry Average Budget	Aggressive: 3.5%/Yr. – 4 Yrs., 2%/Yr. – 6 Yrs.	Aggressive Budget
1999	none	none	N/A	none	N/A
2000	none	none	N/A	none	N/A
2001	none	none	N/A	none	N/A
2002	none	none	N/A	**1-12%**	**$120,000**
2003	none	none	N/A	none	N/A
2004	none	**1-12%**	**$120,000**	**2-18%**	**$ 78,100**
2005	none	none	N/A	none	N/A
2006	none	none	N/A	none	N/A
2007	none	none	N/A	**3-22%**	**$136,500**
2008	none	**2-18%**	**$78,100**	**4-25%**	**$370,500**
Total Cost			**$198,100**		**$705,100**

Projects must be completed prior to October of the year shown. For example, project 1-12% under aggressive growth needs to be completed prior to October of 2002.

With the completion of all five improvement projects, the FG&E gas high-pressure system is capable of adding up to 36% additional firm load to it's present customer base. This translates into an increase of 407 Mcfh, which is an increase of the total system firm load from 1133 Mcfh to 1540 Mcfh. Additional peak hour, firm supply will be required at the 25% load growth level or a total system load of 1392 Mcfh. Contracting for more supply may be necessary at an earlier load growth level if daily system loads increase at a higher rate than peak hour system loads. The Gas Procurement Department within Unitil will make this determination.

Finally, it is the recommendation of this gas planning study that Fitchburg Gas & Electric design and construct any or all of the identified projects based on the load growth scenario chosen as the most beneficial during the Strategic Gas Expansion Initiative.

SPECIAL CONSIDERATIONS

Consideration #1: Currently, the TGP/LPG site and the LNG site supply the FG&E gas system. The preferred source of supply is from TGP because of cost considerations. LNG is used to provide pressure support to the Gardner area on cold days, when the pressures in Gardner reach the minimum design criteria of 40psig. This typically occurs whenever temperatures in the area drop below 10 degrees Fahrenheit. Operating procedures call for the use of Chubbs Pier and Sawyer Passway regulator stations during these conditions. These stations reduce the pressure towards Gardner, allowing the LNG plant to provide more supply back towards Fitchburg. The results of this study show that the use of these stations is not necessary for these cold day situations. Because LNG is a more costly supply, the current operating procedures should be changed. The procedures should no longer show the use of Chubbs Pier and Sawyer Passway stations under these cold day conditions (with the LNG plant operating).

Consideration #2: Project #1-12% will reduce the minimum pressure design criteria to 20 psig. This change increases the capacity of the system by 62 Mcfh. Increasing the capacity of the system in this way will also lower the response time available during first contingency situations. Operating procedures should be developed to mitigate this change. This project will also reduce the need to operate the LNG plant for pressure support purposes. Consideration should be given to completing this project before the recommended time frame of this study due to supply cost considerations (LNG vs. TGP supply costs).

Consideration #3: Backup supply of the LNG and LPG plants is currently part of Unitil's planning criteria for the FG&E gas system. A portable vaporizer is being purchased to perform this function. With the vaporizer in place, the system can survive the first contingency loss of either the LNG or LPG plant during system peak periods. Consideration should be given to establishing operating procedures that allow expeditious employment of the vaporizer. Planning studies should also be performed to define system load levels (by HDD) which trigger an alert status operating procedure. This procedure should detail the steps necessary to deploy the vaporizer. Rapid deployment is extremely important because of the need for tanker truck delivery of fuel and the startup time requirements of the vaporizer.

Consideration #4: The FG&E system is heavily reliant on the operation of the LNG plant under most CWD scenarios. It is the recommendation of this study that the long-term goals of Unitil should include major system piping improvements between Fitchburg and Gardner. This will essentially reduce the reliance on LNG and improve the first contingent performance of the system. This study has made recommendations, which begin this improvement process by reinforcing the piping coming out of the TGP/LPG site as well as the piping from the LNG plant to Gardner. These are the first steps in what should be a long-term improvement plan for the system. Future load studies will determine when and how the improvements should occur. Both Engineering and Operations support this long term goal.

Final Remarks: In closing, it is important to note the many contributions that went into the development and completion of this study. Many have provided help and support to reach this conclusion. Specifically, Fitchburg Operations personnel have played a very important role by providing data, operating experiences, and in the end, support of the study recommendations. The Procurement and Finance Departments of Unitil both provided information essential in completing the study. Also, Customer Service supplied billing information, which was vital to creating the present day model. Lastly, the members of the Strategic Gas Expansion Initiative provided guidance throughout the study. The completion of the 1999 FG&E Gas Planning Study was truly a successful team effort. Thanks to all of you!

APPENDICES